UNITED STATES PATENT APPLICATION

of

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for

WIRELESS SUBSCRIBER TERMINAL PROGRAMMING USING A

BROADCAST CONTROL CHANNEL

WIRELESS SUBSCRIBER TERMINAL PROGRAMMING

USING A BROADCAST CONTROL CHANNEL

FIELD OF INVENTION

The invention relates to wireless systems, and more particularly to the

5   reprogramming of wireless subscriber terminals in a wireless system using a broadcast

control channel.

BACKGROUND OF THE INVENTION

A wireless subscriber terminal ("WST"), also known as a "subscriber" or a

"mobile unit," is any mobile or fixed station providing a subscriber's point of interface to

10   a wireless system, typically a cellular or wireless local loop system. WST's within the

wireless system communicate with a base station, which manages calls across an air

interface by subdividing the available spectrum into a number of voice channels and

control channels. The voice channels carry voice signals and other data. The control

channels carry information needed to manage the voice channels. Broadcast control

15   channels are used to simultaneously transmit information to all of the terminals within

range of a base station, as distinguished from other voice/control channels that operate on

a point-to-point basis. The present invention relates to a system for programming WST's

over a wireless system using a broadcast control channel.

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As telephony techniques have advanced, WST's have become increasingly sophisticated. In addition to radio frequency modulation/demodulation circuitry for transmitting and receiving signals over a wireless channel, WST's typically include signal processing for transforming audio information between analog and digital

5   representations. A microprocessor or microcontroller is also included, both for controlling the voice channel hardware and for providing higher level functions accessible to a WST user. These higher level functions, or "features," include those functions familiar to the typical cellular phone user, such as a call-in-absence indicator, theft alarm, call restrictions, hands-free operation, and handset attributes such as a phone

10   number, security code, and ringer/alert capability.

The microprocessor/microcontroller requires its own software to control initialization of the hardware when the WST is turned on, and to control operation of the WST while it remains on. This software, referred to here as a control program, is stored in a non-volatile memory so that it remains intact until actively erased. Ordinarily, the

15   control program is installed by the WST manufacturer before delivery. The non-volatile memory also typically contains programmable data relating to the identity of the particular WST and the feature settings for the WST. This programmable data is ordinarily entered by a technician prior to delivery to an end user.

The configuration options for WST features can also be programmed remotely.

20   One approach is described in U.S. Patent No. 5,109,403, in which features are activated over a voice channel using tones. In another approach, control channels are used to update WST features, as described in the recent IS-136 cellular specification. While

improving the versatility of wireless systems, these approaches are constrained to setting feature switches, which are then interpreted by the control program to provide features to a WST user. They do not permit replacement of the control program itself.

As control programs and available features change with the passage of time, it is sometimes desirable to update the entire control program associated with a WST, as distinguished from pre-defined features. One method of updating control programs is described in U.S. Patent No. 5,430,877. This approach uses a physical connection to update software. Another approach to reprogramming may be found in U.S. Patent No. 5,666,293. This patent describes a system for programming set-top terminals in a broadcast network such as cable television. These systems permit replacement of control programs, but they are constrained to wired, or physical, interconnections. The latter U.S. Patent, in particular, does not address the limited bandwidth of wireless networks, or the infirmities of a wireless network's air interface.

There remains a need for a system to program WST's, i.e., suitable to wireless telephony, that permits complete flexibility in WST programming/reprogramming from a remote program database.

SUMMARY OF THE INVENTION

In accordance with the invention, the control program in a wireless subscriber terminal is updated by means of control channel transmissions from a base station. The control program is transmitted as a series of messages containing program segments, interleaved with other messages on a broadcast control channel. When a WST identifies

a message as belonging to a control program applicable to the WST, the WST stores the program segment contained in the message.

Reception of the broadcast control channel by a WST can be interrupted by, for example, radio interference, powering down, or movement of a WST beyond the range of a base station. Further, the WST must drop the broadcast control channel and switch to a different physical channel for voice/data traffic. Thus the WST is not always in a condition to receive program messages. To address this problem, the base station arbitrates the transmission of unreceived program segments by polling individual WST's participating in the control program broadcast and retransmitting program segments missed by any of the WST's.

The system preferably provides non-volatile storage of partial programs in each WST so that a WST need not receive an entire program in a single session.

Thus the invention advantageously accomplishes remote WST reprogramming in a manner that avoids use of the voice channels, and in a manner that does not require a continuous, uninterrupted connection to the broadcast control channel.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention description below refers to the accompanying drawings, of which:

Fig. 1 is a block diagram of a wireless communication system;

Fig. 2 is a block diagram of a base station;

Fig. 3 is a block diagram of a wireless subscriber terminal; and

Fig. 4 is a diagram of the message formats used in the invention.

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Fig. 5 is a data flow chart showing the flow of data between a base station and wireless subscriber terminals according to the invention.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

Figure 1 depicts a wireless communication system 10 according to the present invention, in which a base station 20 is in two-way wireless communication with wireless subscriber terminals (WST's) 24, and in further two-way communication with a landline system 25 via a trunk 26. The landline system 25 may be the public switched telephone network (PSTN), or any other wired network capable of voice/data connections. If an active call is present on the trunk 26, the base station 20 translates the forward trunk signal to a properly formatted radio signal which is radiated by an antenna 27 to a WST 24 over the air interface 30. The WST 24 performs complementary operations to establish two-way voice connections over the air interface 30.

The term "trunk," as used herein, refers to a conventional connection to a PSTN for carrying a plurality of telephone signals, and is further intended to include a plurality of such trunks, an individual subscriber line, or any other connection to a landline system 25.

The terms such as "voice channel" and "voice traffic", as used herein, are intended to include the communication of conventional audio signals, as well as data, such as facsimile or computer data, that might be carried by a telephone system 25.

It should further be appreciated that numerous wireless communications systems are known and used worldwide, and the present invention may be usefully practiced with

any of these, or other proprietary or private systems, provided the system includes an air interface 30 having at least one control channel, distinct from the voice channels, which can provide broadcast communication to numerous WST's 24, along with bi-directional control communication between individual WST's 24 and the base station 20. While the

5   invention is intended to be used primarily with a wireless local loop installed as an alternative to a landline, it will be appreciated by those skilled in the art that the wireless communication system 10 may also be a cellular or macro/micro-cellular system designed for mobile telephony and that certain adaptations may be made for such cellular applications.

10   It is particularly contemplated that the invention will be used with more sophisticated, emerging standards such as GSM, PCS, and third generation standards derived from the IMT-2000 program. The following embodiment of the invention uses the digital sector of the air interface 30 described by the Telecommunications Industry Association's IS-136 specification (IS-136). Briefly stated, the digital sector of IS-136 is

15   a digital, time division multiple access (TDMA) technology operating on 800 MHz and 1900 MHz.

As shown in Fig. 1, the IS-136 air interface 30 includes digital traffic channels 32 which are two-way links for voice traffic. The air interface 30 also includes a digital control channel (DCCH) 34 having (logical) broadcast control channels for broadcasting

20   information from the base station 20 to numerous WST's. The DCCH 34 also includes several (logical) point-to-point control channels for direct, two-way control communication between each WST 24 and the base station 20. This combination of

control channels can be advantageously employed to effectively transmit an entire control program to several participating WST's 24 while conserving the typically limited digital traffic channels 32 for voice traffic between the landline system 25 and the WST's 24.

As shown in Fig. 2, the base station 20 provides an interface between the landline system 25 and the WST's 24. In order to function in this capacity, the base station 20 includes a MUX/switch 50 on one hand to transmit and receive wired network voice traffic, and a radio frequency (RF) system 60 connected to the antenna 27 on the other hand to transmit and receive wireless voice traffic across the air interface 30. A wireless access controller (WAC) 70 manages the operations of the RF system 60 and the MUX/switch 50 to ensure that each wired voice connection is coupled to the correct channel of the air interface 30. The WAC 70 also performs functions related to voice encoding, compression, encryption, and security.

With respect to the present invention, the WAC 70 performs several specific functions. First the WAC 70 manages the transmission of a control program over the broadcast control channel. The control program is stored in a memory 80 in the base station 20. In order to transmit the control program to the WST's 24, the WAC 70 divides the control program into program segments which can be interleaved with other broadcast control channel transmissions, i.e., transmitted between other control messages so as to avoid interfering with ordinary operations of the wireless system 10. When it is desired to update the control program for the WST's that is stored in the memory 80 of the base station 20, for example, over the landline system 25, the wireless access

controller 70 also manages the receipt of the control program over a trunk 26 and storage of the control program in the memory 80.

As shown in Fig. 3, a WST 24 transmits and receives signals through the air interface 30 using an antenna 100 coupled to an RF system 110. The demodulated voice signal, or some encoded representation thereof, is carried on a system bus 112 to a voice signal port 114. In the preferred wireless local loop embodiment, the voice signal port 114 is a modular jack compatible with standard local loop telephone cords, along with any appropriate conversion circuitry. The WST 24 also includes a processor 122 connected to the system bus 112 for controlling operation of the WST 24, as well as a memory 124 for temporary storage and a non-volatile memory 126 for storage of a WST control program.

The control program consists of a series of instructions which the processor 122 can execute to control operation of the WST 24. The term "firmware", as used in the following discussion, is intended to refer to an executable firmware image for use with a microcontroller, as well as any other executable code, instructions, or other software that might be used as a control program for a WST 24. Reprogramming the WST 24 with a new control program comprises four general steps: (1) initialization, (2) program broadcast, (3) verification, and (4) switch-over. These steps are now described in detail.

1. Initialization:

Before broadcast transmission of a new control program, the base station 20 directly initializes each WST 24 by sending each WST 24 a *broadcast firmware start (BFS)* message 150 over a forward point-to-point control channel. Figure 4 shows the

format of the *BFS* message 150, which is used by each WST 24 to determine whether it should participate in the upcoming control program broadcast. The *BFS* message 150 includes a hardware model number 152, a hardware version number 154, a firmware version number 156 for the particular control program, and a feature set identifier 158.

5   Each WST 24 compares this information with stored information to determine whether it should receive the impending control program broadcast.

The *BFS* message 150 also includes information which participating WST's 24 use to handle the subsequent broadcast messages containing the new control program. A transfer identifier 160 uniquely identifies the control program broadcast. The same

10   identification number is also included in all of the broadcast messages containing the new control program so that each WST 24 can recognize them. A force transfer flag 162 can direct the recipient WST 24 to load the new control program even when the WST 24 already has a matching firmware version number 156. An automatic switch-over flag 164 can be used to instruct the WST 24 to automatically transfer control to the new control

15   program once a complete program has been received. If the automatic switch-over flag 164 is not set, then the WST 24 waits for a command from the base station 20 to switch to the new control program.

Further flexibility is provided by including, in the *BFS* message 150, a block size field 166 and a number-of-blocks field 168. By transmitting these parameters, the base

20   station can adjust message lengths for a particular control program broadcast.

Each WST 24 receiving the *BFS* message 150 replies with its own *BFS response (BFSR)* message 180. This is a simple two-part message transmitted over a reverse

control channel. The *BFSR* message 180 includes the transfer identifier 160 from the

BFS message 150, and a response code 184 which indicates whether the WST 24 will

participate in the pending control program transfer.

The base station 20 receives a *BFSR* message 180 from each WST 24. This

5 information is stored in the memory 80 of the base station 20 for use during the

reprogramming. At this point, initialization is complete and the base station 20 may

initiate a control program broadcast.

2. Control Program Broadcast:

The base station 20 transmits segments of the new control program using

10 *broadcast firmware block (BFB)* messages 190 transmitted over a broadcast channel.

Each *BFB* message 190 has three parts. The transfer identifier 160 is again used to

uniquely identify the control program broadcast. A block number 194 is included to

allow for proper sequencing of control program blocks. And, of course, the firmware

block 196 itself is included in the *BFB* message 190. The length of the firmware block

15 196 is specified in the (previously transmitted) *BFS* message 150. The *BFB* messages

190 are interleaved with other broadcast channel transmissions within a logical channel

so as to permit other broadcast channel traffic required for normal operation of the

wireless communication system 10.

The base station 20 continues broadcasting *BFB* messages 190 until it has

20 transmitted a complete control program. If the broadcast channel was an error free,

uninterrupted communication medium, this would conclude the firmware transfer.

However, there is no guarantee that every *BFB* message 190 reaches every participating

WST 24. Any number of events may cause a WST 24 to miss *BFB* messages 190, including a user powering off the WST 24, interference in the air interface, equipment failure, or the WST 24 switching to a digital traffic channel 32 for normal call activities. Thus the wireless system proceeds to verify the control program broadcast.

5   3. Verification:

In order to verify the firmware broadcast, the base station 20 polls all of the participating WST's 24 using *broadcast firmware status request (BFSReq)* messages 200, transmitted over one or more forward point-to-point control channels. Each *BFSReq* message 200 includes no message other than its own request for status information.

10   Each WST 24 responds to the *BFSReq* message 200 using a *broadcast firmware status (BFStat)* message 210, transmitted to the base station 20 over a reverse control channel. The *BFStat* message 210 includes a status code 212 indicating the status of the received control program, e.g., transfer incomplete, transfer complete, transfer and switch-over complete. The status code 212 may also contain information available from

15   WST 24 self-tests, such as a hardware failure or unsuccessful switch-over while attempting to use the new control program. These self-tests are described below in reference to the switch-over to a new control program, but they may be conducted before or after the WST 24 receives a *BFSReq* message 200.

As with the other messages, the *BFStat* message 210 includes the transfer

20   identifier 160. Using a blocks received field 216 in the *BFStat* message 210, the WST 24 also informs the base station 20 of the number of blocks successfully received. Finally,

the *BFStat* message 210 includes a missing block mask 218 for identifying those blocks which have not been received.

The missing block mask 218 is a multi-bit mask in which each bit represents a series of control program blocks. In a preferred embodiment, the mask is 64 bits long and each bit is mapped to a sequential, integer number of blocks representing approximately one sixty-fourth of the entire block range. By coding and decoding the missing blocks in this manner with a predetermined formula, each WST 24 can quickly and efficiently inform the base station 20 of block ranges in which there are blocks missing.

At this point, the base station 20 retransmits any missing control program blocks. The collective *BFStat* messages 210 received by the base station 20 provide a complete picture of which blocks are missing from which WST's 24 within the wireless system 10. In order to fill these gaps, the base station 20 may employ a number of strategies. The base station 20 may simply re-broadcast a complete set of missing blocks, or the base station 20 may individually transmit blocks to each WST 24 using forward point-to-point control channels. Where a single WST 24 has missed a significant number of blocks, it may even be desirable to transmit a set of missing blocks using a (higher data rate) digital traffic channel. Alternatively, the base station 20 may analyze the distribution and symmetry of missing blocks to select some mix of these two strategies which optimizes air interface traffic and/or speed. Any methodology can be employed, provided each participating WST 24 has a complete control program prior to switch-over.

4. Switch-over:

The final message type of the reprogramming protocol is a *firmware switch-over*

message 220, transmitted from the base station 20 to a WST 24 using a forward point-to-point channel. Upon receipt of the *firmware switch-over* message 220, the WST 24 stores the complete new control program in non-volatile memory 126 and transfers control to the new control program. Optionally, the switch-over may be automatic, as when the automatic switch-over flag 164 is set in the initial *BFS* message 150.

The old control program is retained after the switch-over. When the WST 24 first transfers control to the new control program, a series of internal verification tests are performed to ensure that the new control program is operating correctly. This includes conventional power-on self tests of memory 124 and system bus 112 input/outputs. Each item of hardware used by the control program, e.g., the RF unit 110, is also tested to ensure that it is present and responding to the processor 122. If the power-on tests are successfully completed, the WST 24 then attempts to access the broadcast control channel used by the base station 20, using the new control program. If any of these tests are failed, the new control program is rejected and the WST 24 restores the old control program. If all of these tests are successfully completed, the new control program is marked as "accepted" (so that subsequent WST power-on's do not result in an inappropriate rejection of the new control program), and control of the WST 24 is unconditionally transferred to the new control program.

Figure 5 shows the flow of data according to the programming method described above. The base station 20 and each WST 24 are shown as vertical lines. The horizontal lines indicate data flow between the base station 20 and each WST 24, with arrows indicating the direction of data flow. The initialization 240 comprises a *BFS* message

150 transmitted from the base station 20 to each WST 24 on a point-to-point basis. Once each participating WST 24 has responded with a *BFSR* message 180, the base station performs a control program broadcast 250 by broadcasting the *BFB* messages 190 containing control program blocks. It will be noted that each *BFB* message 190 is a single broadcast transmission to all of the participating WST's 24. After all of the *BFB* messages 190 have been transmitted, The base station 20 performs a verification 260 of the broadcast. This comprises *BFSReq* messages 200 from the base station 20 to each WST 24 on a point-to-point channel, and a responsive *BFStat* message 210 from each WST 24 to the base station 20. Where firmware switch-over is controlled from the base station 20, a final switch-over step 270 is performed by a *Firmware Switch-Over* message 220 from the base station 20 to each participating WST 24.

A number of variations to this reprogramming system are possible once the basic update system is in place. Each WST 24 may store multiple control programs for use at different times, with the base station 20 controlling each switch-over as needed. Further, the reprogramming system may be used to provide software patches, that is, individual blocks of a control program may be replaced without replacing the entire image.

Although the present invention has been shown and described with respect to a preferred embodiment thereof, it should be understood by those skilled in the art that various other changes, omissions and additions to the form and detail thereof may be made therein without departing from the spirit and scope of the invention.

What is claimed is: